Ad Hoc Group of Scientific Experts
to Consider International
Cooperative Measures to Detect and
Identify Seismic Event

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PROGRESS REPORT TO THE CONFERENCE ON DISARMAMENT ON THE THIRTY-EIGHTH SESSION OF THE AD HOC GROUP OF SCIENTIFIC EXPERTS TO CONSIDER INTERNATIONAL COOPERATIVE MEASURES TO DETECT AND IDENTIFY SEISMIC EVENTS

1. The Ad Hoc Group of Scientific Experts to Consider International Cooperative Measures to Detect and Identify Seismic Events, initially established in pursuance of the decision taken by the Conference of the Committee on Disarmament on 22 July 1976, held its thirty-eighth formal session from 21 to 25 March 1994, in the Palais des Nations, Geneva, under the Chairmanship of Dr. Ola Dahlman of Sweden. This was the thirtieth session of the Group, convened under its new mandate by the decision of the Committee on Disarmament at its 48th meeting on 7 August 1979.

2. The Ad Hoc Group is open to all member States of the Conference on Disarmament. It is also open on a standing basis to all non-member States which have been invited upon their request by the Conference on Disarmament to participate in its work. Accordingly, scientific experts and representatives of the following member States of the Conference on Disarmament participated in the session: Australia, Belgium, Bulgaria, Canada, China, France, Germany, India, Italy, Japan, Korea, Republic of, Netherlands, Russian Federation, Sweden, United Kingdom of Great Britain and Northern Ireland and the United States of America.

3. Scientific experts and representatives from the following non-member States of the Conference on Disarmament participated in the session: Czech Republic, Denmark, Finland, Norway, Spain and Switzerland.

4. Following a request by the Ad Hoc Committee on a Nuclear Test Ban, the Ad Hoc Group of Scientific Experts finalized a report to summarize the knowledge and experience on the upcoming GSE Third Technical Test (GSETT-3). A specific request was for an elaboration on:

- The overall concept of GSETT-3.

- The function and components of the system.

- Matters of organization and cost.

This report has been presented to the Ad Hoc Committee and is provided to the Conference on Disarmament as document CD/1254. The report was presented to the Ad Hoc Committee by Dr. Ola Dahlman. Experts from the Group of Scientific Experts gave presentations to the Ad Hoc Committee's Working Group I on Verification in their national capacities. The experts and subjects covered were Dr. Peter W. Basham (Canada) on seismic techniques, Dr. Frode Ringdal (Norway) on GSETT-3, Dr. Steven R. Bratt (United States) on the GSETT-3 International Data Centre, and Dr. Heinrich W. Haak (Netherlands) on organization and cost.

5. The Ad Hoc Group received and appreciated a briefing from the Chairman of the Ad Hoc Committee on a Nuclear Test Ban Working Group I on Verification.

6. The Ad Hoc Group noted with appreciation the convening of an informal technical workshop in Tokyo, Japan during 14-16 March 1994. The purpose of the workshop was to contribute to the development of GSETT-3. Twenty-three experts from 21 countries attended the workshop.

7. The Ad Hoc Group suggests that its next session, subject to approval by the Conference on Disarmament, should be convened from 8-19 August, 1994, in Geneva. This session will be devoted to further planning and preparations for GSETT-3 and responding to requests from the Ad Hoc Committe and its Working Group I on Verification for specific tasks of a technical and scientific nature.

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25 March 1994

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REPORT OF THE AD HOC GROUP OF SCIENTIFIC EXPERTS TO CONSIDER INTERNATIONAL COOPERATIVE MEASURES TO DETECT AND IDENTIFY SEISMIC EVENTS TO THE AD HOC COMMITTEE ON A NUCLEAR TEST BAN ON INTERNATIONAL SEISMIC MONITORING AND THE GSETT-3 EXPERIMENT

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Table of Contents

	Page
Executive Summary	3
Chapter 1: Background	6
Seismology	6
Detecting and Locating Seismic Events	6
Detection	6
Location	7
Identification	7
CD Group of Scientific Experts (GSE)	8
Chapter 2: Overall Concept of GSETT-3	9
Introduction	9
Overall Design Concept	10
A Global Monitoring Network of Stations	10
An International Data Centre	12
National Data Centres	13
Chapter 3: Functions and Components of GSETT-3	14
Introduction	14
GSETT-3 Elements	14
GSETT-3: Current status and future plans	15
What can GSETT-3 Provide to the NTB Committee?	17
Chapter 4: Matters of Organization and Cost	19
Organization of GSETT-3	19
Cost Estimates for GSETT-3	19
Annex 1: Technical Characteristics of a Standard ISMS Station	21
Annex 2: GSE Reports to CD	23
Figures: 1 to 5	24

Executive Summary

Following a request by the Ad Hoc Committee on a Nuclear Test Ban, the Ad Hoc Group of Scientific Experts finalized a report to summarize the knowledge and experience on the upcoming GSE Third Technical Test (GSETT-3). A specific request was for an elaboration on:

- The overall concept of GSETT-3.
- The function and components of the system.
- Matters of organization and cost.

The Ad Hoc Group of Scientific Experts (GSE) has reported on a number of occasions to the Conference on Disarmament on its activities to develop and test the concepts for an International Seismic Monitoring System (ISMS) for detecting the seismic signals produced by a nuclear explosion detonated underground. These activities are collectively known as GSETT-3, or the GSE Technical Test Three. This ambitious experiment, which is already underway will be a realistic test on a global scale of the new concepts of the ISMS. These new concepts include: a single centralized International Data Centre; a specifically designed high-quality seismographic network; and a modern communications system providing continuous data to the international centre.

It is planned that the test will involve more than 100 seismological stations distributed world wide in more than 40 countries and a centralized International Data Centre (IDC). The GSETT-3 should provide the practical experience and infrastructure which could be used by the Conference on Disarmament to establish a seismic monitoring system for a CTBT. The major pieces of the infrastructure to be developed and tested are the network of seismological stations and the International Data Centre.

The ISMS concept of a global network of stations is a two-tiered system. The most important tier is made up of the highest quality stations which are located, in so far as possible, at carefully chosen sites where the background noise (which limits the detection of signals) is very low. These stations are described as Alpha stations and the data from these stations would be transmitted continuously to the IDC. For GSETT-3, a total of 57 of these sites have been identified with stations in 34 countries and Antarctica to cover all the continents. In most cases, high quality stations already exist at these sites. These stations have been chosen to meet criteria established by the GSE for sensitivity, operations and geographical distribution.

The second tier of stations are called Beta stations and are, in general, equipped with simpler sensors, but nevertheless conform as close as possible to the high standards of the Alpha stations. They are supplementary to the Alpha stations and are intended primarily to provide additional seismological data as needed to improve the accuracy of the location of a seismic disturbance initially detected by the Alpha network. The data from the Beta stations will be accessed on an automatic basis only as required by the IDC. It is anticipated that the number of Beta stations around the world would exceed the number of Alpha stations.

The GSETT-3 concept also includes the incorporation of other supplementary data from networks of national seismographic stations not specifically designed for the detection of nuclear explosions but rather used to monitor the earthquakes within or close to national territories. Data from these networks would be provided on a voluntary basis by national authorities. Information on small local seismic disturbances could well be provided by the parties which operate such national networks upon a request from the IDC.

The International Data Centre is the focal point for the GSETT-3 system acting as the data collection and distribution facility for the entire network. The IDC would provide products and services to all the participants in GSETT-3 on an equal basis. Two important products are the basic raw sensor data from all of the stations in the network and a listing of all seismic events around the globe detected by the system giving the time of occurrence, location, and other information to describe the event. The IDC would also provide permanent storage of all the data collected in the system. The IDC also oversees the overall operation of the global network of stations.

To organize an effective management system, the ISMS concept proposes that participating States establish National Data Centres (NDCs) to serve as an interface between the seismic network and the IDC. Each participating State would receive data and processed results from the IDC through these centres.

The GSE plans to test the experimental ISMS in a way that matches as closely as possible the design concepts outlined above. Over the past year, substantial progress has been made in establishing facilities and starting operations for the test. There has been rapid progress in establishing and starting operations of the IDC, located in Arlington, Virginia, United States. It is expected that during GSETT-3 the IDC will have an international staff of 40-50 people. The entire experiment is being implemented in stages, with a plan to build up to full-scale operations beginning in January 1995. Most of the Alpha stations exist today and a number of new stations are being established through national or cooperative international efforts. Modern communications links must be installed for both the Alpha and Beta stations in the network.

The full GSETT-3 Alpha network, when put into operation would provide a capability to detect seismic disturbances down to a magnitude of between 3 and 3 1/2 on the Richter scale. A network with good global coverage is essential to meet the objectives of GSETT-3. At this time, only 20 of the 57 Alpha stations (12 of 34 countries) have been committed by their host countries. It is, therefore, most important that those countries, most of whom are members or observers to the CD, that have not yet committed the needed facilities to the GSETT-3 provide the required stations as soon as possible. Countries may, through bilateral or multilateral cooperation, provide technical and financial assistance to other countries whose participation is essential.

Considerable investment has been made in developing the facilities to be used in the GSETT-3. The total investment to date totals about 150 million US dollars (Alpha stations - $100 M; Beta stations - $10 M; Communications - $10 M; and the IDC - $30 M). A total new investment of about 27 million US

dollars is planned on the GSETT-3 facilities in the near future. The annual operating costs for GSETT-3 is about 26-30 million US dollars with the cost of the Alpha network, communications, and the IDC being about equal.

There are a number of ways in which the GSETT-3 experience can provide contributions to the Nuclear Test Ban Ad Hoc Committee in its negotiations. The GSETT-3 could provide inter alia the following information relating to a future seismic monitoring system:

- The station network designed for GSETT-3 could provide a basis for the design of the ISMS.

- The functions and products which have been designed for the IDC could be a guide to the functions and products required for monitoring purposes.

- The detailed instructions and procedures developed for GSETT-3 could provide a good foundation for Operating Manuals for the components of the ISMS.

- The facilities (IDC, seismological stations of the networks) could provide a valuable infrastructure that could facilitate the implementation of an ISMS under a treaty.

- The experiences in GSETT-3 could be useful in estimating system capabilities, costs and staffing requirements.

In view of these considerations, the GSE expects GSETT-3 to represent a major contribution to the advancement of a prototype operational ISMS. Nevertheless, it is important to note that as an experimental system, the global network in operation during GSETT-3 will not provide all the capabilities that might be required by a seismic monitoring system under a future CTBT.

Chapter 1

Background

Seismology

Seismology is the science of earthquakes and includes the study of seismic waves from sources such as earthquakes and explosions. The recording by seismograph stations and the study of seismic waves allows seismologists to determine the nature and location of a seismic source, and to study the internal structure of the earth. The best method of detecting a fully contained underground nuclear explosion (one which does not vent radioactive materials to the surface) is to record the seismic waves generated. A network of seismic stations is therefore an essential element in the monitoring system that would be put in place to assist in the verification of compliance with a ban on underground nuclear tests. However, seismic means make it possible to detect nuclear explosions in other environments also, e.g. underwater.

Earthquake research expanded slowly in the early part of this century, aided by the first world-wide seismograph networks established at the turn of the century. Much of the early impetus came from the need to understand the causes of large disastrous earthquakes: San Francisco, United States, 1906, and Kwanto, Japan, 1923, to name just two. The early seismograph networks in many countries were installed in response to damaging earthquakes. By the 1950s, the science of seismology was carried out by several institutions acting independently on each of the major continents, with ad hoc procedures for data exchange following very large damaging earthquakes. It was the need to monitor underground nuclear testing that produced a major leap in the science beginning about 1960. Global networks of standardized instruments were installed, at first with analog recording and later with digital recording to facilitate data processing and analysis with computers.

There are, on average, more than 7,000 earthquakes per year around the world that are larger than seismic body-wave magnitude 4 (Figure 1). A magnitude 4 disturbance is large enough for humans to feel shaking if they are within about 100 km from the earthquake source. This is also the seismic magnitude produced by a fully contained and coupled explosion in hard rock with a size of approximately one kiloton. The numbers of natural earthquakes increase by a factor of about 8 for each decrease of 1 magnitude unit (i.e. there would be about 60,000 earthquakes per year larger than seismic magnitude 3). The detection capability for smaller earthquakes is not uniform around the globe. Some national seismograph networks can detect seismic events within their networks down to small magnitudes, but there are many regions of the globe where there are too few seismograph stations to detect below about magnitude 4.5.

Detecting and Locating Seismic Events

Detection

Modern seismometers (the sensor component of the seismograph) can detect ground movements as small as the size of atomic spacing, and thus in principle can detect the seismic waves from very small seismic events. However, not

only the events of interest cause vibrations in the earth. Natural processes such as wind and ocean waves and cultural activity such as automobile traffic and factories generate continuous vibrations, "seismic noise", that is also recorded by the seismographs. An event of interest can be "detected" only if the signal produced by its seismic waves exceeds the seismic noise. The nature and level of seismic noise will vary considerably with location. The quietest sites for seismographs are near the centre of large continents, away from the influence of ocean waves, and a few tens of kilometres away from significant human activity. There are many such sites on earth, and these are the locations of the seismographs producing the best detection capability of seismic events globally.

Detection of seismic waves can also be enhanced by signal processing, particularly when applied to the recordings from a seismic array. A seismic array is a cluster of seismometers distributed over a small area, typically a few to about 20 km across. During data processing, the array can be "steered", like an antenna, to detect the oncoming direction and speed of the seismic wave, which in turn can provide an estimate of the location of the seismic source. By adding the signals from the individual seismometers together, the detection capability is improved by increasing the signal relative to the noise. Typically, an array can lower the detection threshold by at least one-half magnitude unit relative to a conventional seismograph station. This corresponds roughly to a factor of three or more when converted to explosion yields.

Location

Once a seismic event has been detected, an accurate location must also be established. Although a single array can provide an estimate of the location of the seismic source, this estimate usually has a large uncertainty if it is in the "teleseismic" distance range, 3,000 to 10,000 km from the array. It is more common to consider locations based on computations using the time that seismic waves are recorded at a minimum of three or four stations or arrays. It is difficult to generalize about accuracy achievable in seismic event locations, which depends on both the numbers of stations and arrays detecting the events and on the precision with which the seismic wave speeds are known within varying and often complicated geological structures of the earth. With data from a number of nearby stations a good location may be determined with a precision of better than 5 km; whereas with data only from distant stations a good location may have a precision of about 20 km. High accuracy in locating seismic events can also be achieved by a seismic array if appropriately calibrated. This becomes important in the verification process because it gives an indication of the size of the land area that may have to be covered by an on-site inspection.

Identification

Seismological research into discrimination between earthquakes and underground explosions has been carried on for more than three decades. It must be emphasized that the problem of seismic event identification is a very complex issue, and it has not yet been discussed in detail in the GSE.

During GSETT-3, a number of parameters which may be useful for the identification of seismic events will be compiled by the International Data Centre (IDC) and provided to participants for their national assessment. The availability of seismic waveform data at the IDC will be of key importance to providing this information.

CD Group of Scientific Experts (GSE)

In 1976, the Conference of the Committee on Disarmament established the "Ad Hoc Group of Scientific Experts to Consider International Cooperative Measures to Detect and Identify Seismic Events", now commonly known as the "GSE". The Group was asked to "specify the characteristics of an international monitoring system, including the costs which would be incurred if an international monitoring system were established". The Group "would endeavour to estimate the detection and identification capability of such an international cooperative system ... but should not, however, assess the adequacy of such a system for verifying a comprehensive test ban".

In 1984, the GSE conducted its first global test (GSETT-1) which consisted of the exchange of basic parameter data of seismic events using the low capacity communications circuits of the World Meteorological Organization. This system proved inefficient and was far too restrictive in the amount of information that could be collected and analysed.

Based on the experience from GSETT-1, the GSE conducted its second test in 1991, using more modern communications facilities to exchange selected segments of waveform data from 60 seismograph stations in 34 countries. The data was analysed in four centres concurrently. The experiment demonstrated the need to carefully select the network of stations based on specific technical requirements and showed that there was no need for four analysis centres.

The planned GSETT-3, draws upon the results of the first two experiments and builds upon the recommendations and experiences of these tests. This ambitious experiment, which is already underway, will be a realistic test on a global scale of the new concepts. These new concepts include: a single centralized International Data Centre; a specifically designed high-quality seismographic network; and a modern communications system providing continuous data to the international centre.

The GSE has prepared a number of comprehensive consensus reports to the Conference on Disarmament describing the work that the Group has undertaken and the results of the large scale and smaller scale tests carried out by the Group. A bibliography of reports by the Group is attached in Annex 2.

Chapter 2

Overall Concept of GSETT-3

Introduction

In the course of its work, the Group of Scientific Experts has developed several concepts for an International Seismic Monitoring System (ISMS) and conducted two technical tests to assess the performance of these concepts. As part of the Group's Third Technical Test (GSETT-3), the Group has advanced and refined these concepts and is now embarking on an operationally realistic test of this new generation of concepts. The overall concepts which are being developed and tested as part of GSETT-3 are described in this chapter. Additional details of the concept can be found in documents submitted by the GSE to the CD, including CD/1211 (August 1993) and CD/1245 (March 1994).

GSETT-3 has three additional objectives that distinguish it from previous tests. These objectives are to:

(a) Develop and test new concepts for an experimental International Seismic Monitoring System, building upon previous experience;

(b) Provide a practical basis upon which to furnish the Conference on Disarmament with timely technical information;

(c) Develop an experimental system that can evolve and adapt to support future requirements that may be specified for an International Seismic Monitoring System.

The International Seismic Monitoring System is aimed primarily at detecting the seismic signals generated by a nuclear explosion detonated underground. The essential features of the ISMS are to:

- Provide rapid acquisition of data from a global network of seismic sensors and processing of this data at a central processing facility;
- Ensure prompt distribution of all data to all participating States for their national verification purposes;
- Provide as much automation as possible in the collection, processing, and distribution of data;
- Provide a permanent archive of all data collected or generated by the ISMS;
- Provide data security and quality control;
- Provide a cost-efficient service to all participating States;
- Establish a monitoring system architecture which is flexible enough to allow any technical modifications and improvements which may be needed in the future.

Overall Design Concept

The ISMS encompasses an integrated network of highly capable seismic sensors, a modern communications network, an International Data Centre and National Data Centres to collect and distribute the monitoring data. The overall system must accomplish its monitoring functions rapidly and reliably, and provide results in a cost- effective manner. Hence, the ISMS must incorporate a high degree of automation in its operations. The principal components of the International Seismic Monitoring System are the following:

- A global monitoring network of seismograph stations meeting agreed rigorous technical specifications. The stations of this network are specifically designed and located to provide detection of seismic events throughout the world. The operation of the stations are designed to ensure uninterrupted streams of reliable data, even from stations located in remote areas.

- An International Data Centre (IDC) which receives the data from the monitoring network, applies standard processing techniques to these data, and provides this information, along with other "standard services," to the National Data Centres of participating States. All data received at the IDC and the data products created at the IDC are archived and provided for open access by any participating State.

- National Data Centres (NDCs) established in participating States. The NDCs can receive any or all of the data collected at the IDC and the standard service products supplied by the IDC. The NDCs also compile supplementary naticnal data on seismic activity and may submit this information to the IDC.

A Global Monitoring Network of Stations

The global seismic monitoring network is a two-tiered network of Alpha and Beta stations. The first tier of stations, or Alpha stations, is to be composed primarily of arrays of sensors, with some three-component stations, which would provide for the detection and initial location of seismic events on a global basis for the ISMS. The second tier of stations, or Beta stations, would provide supplementary data so that events detected by the Alpha stations could be located with improved accuracy.

Participating States may also make available supplementary data from national and regional seismic networks that are not formally part of the ISMS. This national information is referred to as Gamma data.

The general concept for the Alpha network is as follows:

- The equipment at the Alpha stations would meet defined minimum technical specifications as regards sensitivity, instrument response, recording hardware and software, operation, and management. These specifications have been chosen because they are appropriate to the detection of signals from underground nuclear explosions. The GSE has defined the specifications that should be

met by these "ISMS-standard" stations. This does not mean that these facilities must consist of identical components, but the components of these systems must meet basic functional and technical requirements. If the technical components meet these criteria, instruments could be configured in many ways so that the ISMS standard stations could be tailored to the local site conditions and coupled to the overall network configuration to achieve an adequate global monitoring capability. The standard technical characteristics of the equipment in an Alpha station are provided in Annex 1. The operation of the stations would be automated to the highest degree possible.

- The stations of the Alpha network must be globally distributed in such a way as to take into account areas with good signal recording conditions and to provide an overall global coverage for the detection of underground nuclear explosions. The concept for the ISMS calls for at least 50 stations of this type to be the "backbone" of the global network. As a general principle, the stations should be located at "quiet sites," i.e., sites where the noise disturbances are minimal. This number (at least 50) of stations is based on well-founded seismological considerations provided the stations, as far as possible, are uniformly spread over the globe. Based on experience from technical tests, results of computer simulations, and extensive technical investigations, the Alpha network consisting of 57 stations (see Fig. 2) has been initially defined and will be tested during GSETT-3.

- Each of the stations of the Alpha network would have a reliable communications system for transmittal of data to the IDC. Waveform data from the stations of the Alpha network would be telemetered continuously to the IDC, either directly or uninterrupted through an NDC. These stations would also be provided with on-site backup recording in case of communication outages.

The general concept for the Beta network is as follows:

- Beta stations are primarily three-component stations, with some arrays. To the extent possible and practicable, the Beta stations should conform to the technical specifications and standards of Alpha stations.

- Data from Beta stations must be immediately available to the IDC. Though not telemetered continuously to the IDC, waveform segments can be retrieved automatically by the IDC from the Beta station or from an archive at the National Data Centres containing the continuous data from a Beta station. This requirement also demands a reliable communications system for on-demand access to the data from these stations.

- The GSE has recommended that at least 100 stations of this type be part of the overall ISMS network.

The preliminary concept for Gamma data is as follows:

- Participating States may also make available to the IDC supplementary data from national and regional networks which are operated by those States and which are not formally part of the ISMS.

- The national and regional networks from which the Gamma data are derived are maintained to individual national or regional network standards.

- Gamma data can also be made available by request but the rapidity of response may vary from one national or regional network to another.

An International Data Centre

The International Data Centre is the focal point for the ISMS, acting as a data collection, processing and distribution facility for the network. The IDC would provide data organization function, data archiving, and data products for the benefit of all participating States.

- The IDC would receive all of the seismic data transmitted over the communications circuits from the Alpha and Beta stations. Continuous data from the Alpha stations would be received by continuous telemetry and data segments from Beta stations would be retrieved automatically by the IDC.

- The IDC would process the data from the Alpha and Beta stations to produce a worldwide listing of seismic events. The listing of events would include: the location, the time of occurrence, the depth of origin, the size (magnitude) of the event, and other standard seismological parameters to describe the event.

- The analysis procedures at the IDC would be automated to the degree possible. The procedures should be validated, well-documented and follow strict rules and schedules. All procedures should be repeatable so that results are reproducible. The standard analytical procedures to be carried out at the IDC and the standard services to be provided by the IDC would be documented.

- All data from the ISMS network received at the IDC would be checked for quality and assurity and placed in an archive. This archive would include all waveforms received and all of the data products generated by the IDC, e.g., event lists, bulletins, and detection lists. The IDC would also collect and archive other seismological information (Gamma data) received from the National Data Centres. The volume of data to be collected and archived at the IDC would be significant.

- The IDC would monitor the calibration of the Alpha and Beta stations and ensure overall quality control of the data of the

ISMS. The IDC would also monitor the status of stations and communications and provide quality status information to the NDCs.

- The IDC would be an open facility with all data and processing results easily and openly available to all participating States. Data and processing results not older than 15 days should be available for on-line access, and data older than 15 days should be available within 24 hours.

- Carrying out the work at the IDC would be a joint international effort.

National Data Centres

The National Data Centres serve as the interface between a participating State and the international component of the ISMS. The NDC is the window through which each participating State receives raw data from stations of the ISMS and processed results from the IDC.

- NDCs would be established by participating States to send and/or receive data from the IDC.

- Alpha data would be transmitted continuously to the IDC either directly or through an NDC.

- Automatic access to the data from the Beta stations may be either through the NDCs or directly to the stations themselves.

- Gamma data would be compiled by the NDCs. The procedures for reporting and using this Gamma data are still being elaborated by the GSE.

Chapter 3

Functions and Components of GSETT-3

Introduction

The GSE intends to test in GSETT-3 an experimental International Seismic Monitoring System (ISMS) that matches as closely as possible the design concepts outlined in Chapter 2. It is an important consideration to try to test all the key elements and features of the ISMS concept at least somewhere, if not everywhere, within the GSETT-3 system.

An important aspect of GSETT-3 is to plan and conduct the experiment in such a way that it can be adequately and effectively evaluated. The GSETT-3 system must thus provide the data necessary to demonstrate the viability and performance of the ISMS concept. In particular, the cost of such a system must be assessed.

By computer simulations, the GSE has estimated the event detection and location capability of the GSETT-3 system, given specific event definition criteria. It should be investigated during GSETT-3 whether these theoretical capabilities are actually attained in practical operation. To validate the GSE concept of an Alpha plus Beta station network explained earlier, it must be demonstrated that this network provides event locations that are clearly better than those obtained using the Alpha network alone.

GSETT-3 Elements

The various elements to be tested during GSETT-3 (Alpha and Beta stations, National Data Centres, and an International Data Centre) will, to the extent possible, be established and operated in accordance with the design concept outlined in Chapter 2.

The number of Beta stations in GSETT-3 is expected to be much larger than the number of Alpha stations. A specific network of Beta stations for GSETT-3 has, however, not yet been defined by the GSE. Several countries have offered such stations, and efforts are underway to identify additional candidate stations around the world that would meet the requirements. An optimum configuration for a Beta-station network is being developed in order to provide a basis for identifying potential host countries which would be requested to make a commitment to contribute data from these stations during GSETT-3.

NDCs (or in some cases regional data centres) will be established in participating countries and will be responsible for the maintenance of the Alpha and Beta stations and their communications links during GSETT-3.

The scope of the work and responsibilities at each NDC will vary according to the facilities and resources available and will depend on the requirements of each participating State with regard to national verification procedures.

If Gamma data is to be reported, the NDC will be responsible for collation and submission of Gamma data reports to the IDC.

One of the most important functions of NDCs during GSETT-3 will be to participate in the evaluation process. In order to contribute to the ongoing evaluation of GSETT-3, NDCs will be responsible for collating statistics on their NDC and station operations and for sending feedback reports on various aspects of the IDC performance.

Detailed analysis of IDC products may be performed at NDCs with particular emphasis on the assessment of event location accuracy within their geographic region. NDCs may submit requests to the IDC for waveform data from any station in the network.

The GSE has accepted the offer of the United States to develop and host the experimental IDC for GSETT-3 in Arlington, Virginia. The procedures used at this experimental IDC will follow, as far as possible, the procedures currently envisaged for the eventual IDC. Thus, the procedures will be validated, fully documented and follow strict rules and schedules, and will be as automatic as possible. The products and services of the experimental IDC will include:

- an automatically produced seismic event list based on Alpha station data within one hour;
- an automatically produced seismic event list based on Alpha and Beta station data within four hours;
- a final seismic event bulletin within two days, containing high-quality, analyst-reviewed event solutions.
- a continuous assessment of the capability of the network providing information regarding the lowest magnitude at which events may be detected and any global variations in this magnitude level. This information will be provided on a routine basis and in response to requests from participants.
- system monitoring data and graphic displays of the status of all key components of the GSETT-3 system.
- organized access to all the data received and produced by the IDC.

GSETT-3: Current status and future plans

Over the past year, substantial progress has been made regarding the preparations for GSETT-3. Particularly noteworthy is the rapid progress in

establishing and starting operations at the IDC. Plans for conducting and evaluating GSETT-3 have been developed in considerable detail, and are documented in the GSE progress reports.

Several countries have committed stations and national facilities to participate in GSETT-3, although formal commitments of participation are still urgently needed from a number of countries. The status on participation is summarized in the GSE progress reports.

Most of the stations which have been identified as forming the GSETT-3 Alpha network exist today, but are not yet sending data continuously to the IDC. A number of new stations will have to be established through national or cooperative international efforts. Modern, high-speed communication links will be established for both the Alpha and Beta stations in the experimental network. The GSE foresees a gradual establishment of the network by adding stations when they are completed or made available.

There will also be a gradual implementation of the Beta stations which will be chosen in such a way as to create the best possible network from those stations which are made available to the GSETT-3 network.

Both Alpha and Beta stations will be subjected to acceptance tests prior to being incorporated into the experimental system. An acceptance test of the International Data Centre will also be carried out. Furthermore, the GSE will conduct an ongoing assessment during GSETT-3. Results will be continually incorporated into the system to improve its performance so that the system will be capable of supporting future requirements by the Conference on Disarmament relating to the monitoring of a comprehensive nuclear test ban treaty.

The GSETT-3 International Data Centre is being implemented in stages. The number of stations available and number of days processed per week will increase steadily from the initial IDC implementation in early 1994 (6 Alpha and 13 Beta stations; data analysed 2 days per week) to the eventual IDC implementation 1 January 1995 (full GSETT-3 network; data analysis 7 days per week).

There has been rapid progress in establishing and starting operations of the IDC, located in Arlington, Virginia, United States. The IDC is now functioning and receiving data from stations of the Alpha network as they become operational and communication links are established. During GSETT-3, it is planned that the IDC will have an international staff of 40 to 50 people. The selection of this staff is now underway. An organizational structure within the IDC has been put into place to carry out all of the IDC functions.

Details on the implementation schedule of GSETT-3 are provided in the GSE progress reports.

Although it is recognized that the commitments required from participating States will involve allocation of considerable resources, it is difficult to give any precise indication of the duration of the experiment. For financial

planning purposes, countries participating in GSETT-3 should be prepared to support their national facilities and their communication links for a minimum of 1 year after the start of the full-scale experiment.

What Can GSETT-3 Provide to the NTB Committee?

The GSETT-3 system will provide experience with data and services needed by the national verification programs of the participating States for monitoring a CTBT. These products, which have been described in this report, will be made available through the experimental IDC.

GSETT-3 will provide an infrastructure in the form of technical facilities, including education and training of personnel, which could facilitate the implementation of a monitoring system for verifying compliance with a CTBT.

More specifically, GSETT-3 could provide, inter alia, the following information relating to a future International Seismic Monitoring System (ISMS), which could be useful to the NTB Committee in their negotiations:

- The station network designed for GSETT-3 will provide a basis for the design of the ISMS.

- The functions and products which have been designed for the experimental IDC will be a guide to the functions and products required from the ISMS for monitoring purposes.

- The detailed instructions and procedures developed for GSETT-3 will provide a good foundation for an Operating Manual for the components of the ISMS.

- The hardware and software developed at the experimental IDC and at existing and new seismological stations, and the experience gained by system operators around the world, will provide a valuable infrastructure that could facilitate the rapid implementation of the ISMS.

- The results and experiences which will be obtained as GSETT-3 evolves will be useful in modifying the system design, in estimating system capabilities, costs, staffing requirements and operating instructions of the ISMS.

- GSETT-3 will serve to validate theoretical assessments of the detection capabilities around the world of the proposed Alpha network configuration.

The GSE has conducted extensive theoretical studies of the projected detection capability of the GSETT-3 network under various scenarios. An example is given in Fig. 3, requiring 3 or more detections to define a seismic event. The 90 per cent detection threshold ranges from below 3.0 in parts of Europe and North America to above 3.4 in continental parts of the southern hemisphere.

The detection threshold is slightly higher in the ocean areas, but an explosion in the ocean would be subject to detection by hydroacoustic sensors. Based on GSETT-3 experience, it could be possible to design future monitoring networks with predefined detection thresholds and location accuracies, using computer simulations.

The experimental IDC will not provide identification of detected seismic events, but will calculate and compile agreed parameters characterizing the detected signals that may assist participating countries in identifying the source of each seismic disturbance.

The GSE expects GSETT-3 to represent a major contribution to the advancement of a prototype operational ISMS. Nevertheless, it is important to note that as an experimental system, the global network in operation during GSETT-3 will not provide all the capabilities that might be required by a seismic monitoring system under a future CTBT.

Chapter 4

Matters of Organization and Cost

Organization of GSETT-3

The organization responsible for the oversight of the Group of Scientific Experts Third Technical Test (GSETT-3) is presented in Fig. 4. The Coordinators of GSETT-3 are the GSE's Chairman, Dr. Ola Dahlman of Sweden, and its Scientific Secretary, Dr. Frode Ringdal of Norway. It is primarily through the Coordinators that the plans and results of the test will be communicated to the Conference on Disarmament and the Ad Hoc Committee on a Nuclear Test Ban.

Reporting to the Coordinators are the Working Groups on Planning, Operations and Evaluation, each with an important and distinct responsibility for overseeing the work of GSETT-3. Each Working Group is lead by a Convenor, is staffed with a small number of officially-designated members, and can call upon other GSE participants to support important tasks. The Convenors are Dr. Svein Mykkeltveit of Norway (Working Group on Planning), Dr. Ken Muirhead of Australia (Working Group on Operations) and Dr. Bernard Massinon of France (Working Group on Evaluation). The responsibilities of each group are described in the Progress Report of the GSE's thirty-seventh session (CD/1245).

Working under the guidance of the Working Groups are the organizations responsible for the actual conduct of GSETT-3 (Fig. 5). The central operational facility is the IDC, which is organized into four offices under the management of a Director. The Office of Administration is responsible for finance, personnel, meeting support, visitor support, language services, travel, publications, public information, and office services. The Office of Infrastructure Operations is responsible for the operation and maintenance of the facilities, computers, systems software, global communications, data acquisition, data management, data provision and security.

The Office of Monitoring Operations is responsible for monitoring seismic network operations, and performing automated processing and interactive analysis of the incoming data. The Office of Technical Support is responsible for internal system evaluation, system optimization, software development, documentation and testing. Each NDC will be organized differently, according to its own national verification requirements. However, their international responsibilities during GSETT-3 include the operation of national Alpha and Beta stations to GSE standards, performance of designated system evaluation tasks, and the voluntary provision of Gamma data to the IDC.

Cost Estimates for GSETT-3

The GSE has made an analysis of the overall costs of GSETT-3 and has reported the initial results to the Conference on Disarmament (CD/1211). The costs fall into three general categories. First, there are the previous investments. The ISMS being tested in GSETT-3 draws heavily on these prior investments in facilities for global monitoring of nuclear explosions and seismicity which have been developed on a national basis or as the result of

cooperation between countries. Second, there are new investments that are being undertaken specifically in preparation for GSETT-3, including installation and improvement of seismic stations, communications, and processing systems at the IDC. Third, there are the ongoing costs for the operation and maintenance of all the elements of the ISMS during GSETT-3.

The following table summarizes the costs for the ISMS during GSETT-3 in these categories:

Element	Prior Investment	New Investment	Annual Operating Costs
Alpha Network	$97 M	$14 M	$7 M
Beta Stations	$10 M	$4 M	$4 M
Communications	$10 M	$1 M	$8 M*
International Data Centre	$30 M	$8 M	$7 M
Total	**$147 M**	**$27 M**	**$26-30 M**

* Preliminary, could be up to $12 Million.

As seen from the above table, considerable investment has already been made in developing the facilities to be used in the GSETT-3. The total investment to date totals about 150 million U.S. dollars, and a total new investment of about 27 million U.S. dollars is planned on the GSETT-3 facilities in the near future. The annual operating cost for GSETT-3 is about 26-30 million U.S. dollars, with the cost of the Alpha network, the communications, and the IDC operations being about equal. No cost estimates have been made for investment in the operation of the NDCs, including the provision of Gamma data for GSETT-3.

The Alpha network will be composed of about 30 arrays and about 25 three-component seismic stations. New investment in facilities will include the installation of five new arrays and the upgrade of about 15 three-component stations. Currently available facilities will be used as much as possible. The costs for the installation of seismic facilities, both in the prior investments and for the new investments, can vary considerably from site to site. It is expected that the average cost to install the new arrays for GSETT-3 will be about 2-3 million U.S. dollars.

Annex 1

Technical Characteristics of a Standard ISMS Station

A standard ISMS three-component station would consist of the following elements:

- Three-component broadband seismometers
- A data acquisition system with digitizers to convert the seismometer output signals into digital form and modules for placing authentication signatures into the data stream;
- Electronics for very accurate synchronization to Universal Time;
- A system for transmitting data continuously to (Alpha stations only) or making data available for automatic retrieval (Beta stations) by the IDC, as well as managing the flow, calibration and archival of the data.
- Devices for data archiving;
- Communication interfaces for data transmission to NDCs and the IDC; and
- Data channels for additional input signals (e.g. wind indicators, temperature, and other environmental data) and station status indicators.

Some of the data handling facilities may be at the NDC rather than at the station.

A standard ISMS array would consist of all of the elements above plus additional vertical component short-period sensors distributed to enhance the signal-to-noise ratio and to provide azimuth and phase identification information.

Detailed station requirements that are recommended for a standard ISMS station are given in Table 1. This table is <u>not</u> phrased in layman's language, and serves to illustrate the level of detail needed to specify technical requirements for the elements of a seismic monitoring system.

Category	Requirement
Pass Band	.02-20 Hz (Alpha and Beta)*
Seismometer Noise	10 dB below Peterson's low earth noise model
Calibration	within 5% in amplitude and 5^{o} in phase
Sample Rate	40 samples per second ($\pm$ 50 μs)
Resolution	18 dB below Peterson's low noise model
Sensitivity	200 counts/nm @ 3 Hz
System Noise	10 dB below Peterson's low earth noise curve
Dynamic Range	126 dB
Linearity	90 dB over the pass band
Timing Accuracy	1 ms (Network standard timing required)
Operating Temperature	-10^{o} C to 45^{o} C
Authentication	required
State of Health	a minimum of clock status, calibration status, and vault status
Format	must be one of the official GSE formats
Protocol	TCP/IP (Beta)
Delay in Transmission	< 15 seconds
Data Frame Length	< 1 second
Data Access	Priority given to IDC, then NDC
Disk Buffer	7 days
Data Availability	greater than 99%
Timely Data Availability	greater than 98%
Station Location	known within 100 m; relative location of array elements known to within 1 metre
Seismometer Orientation	known within 1 degree

* 8.0 Hertz for stations with "unique" capabilities

Table 1. Station requirements for an ISMS standard station (from CD/1211).

Annex 2

GSE Reports to CD

CCD / 558	March 1978	- initial concept and design
CD / 43	July 1979	- technical elaboration
CD / 448	March 1984	- technical elaboration
CD / 720	July 1986	- report on GSETT - 1
CD / 903	March 1989	- revised concept
CD / 1144	March 1992	- report on GSETT - 2

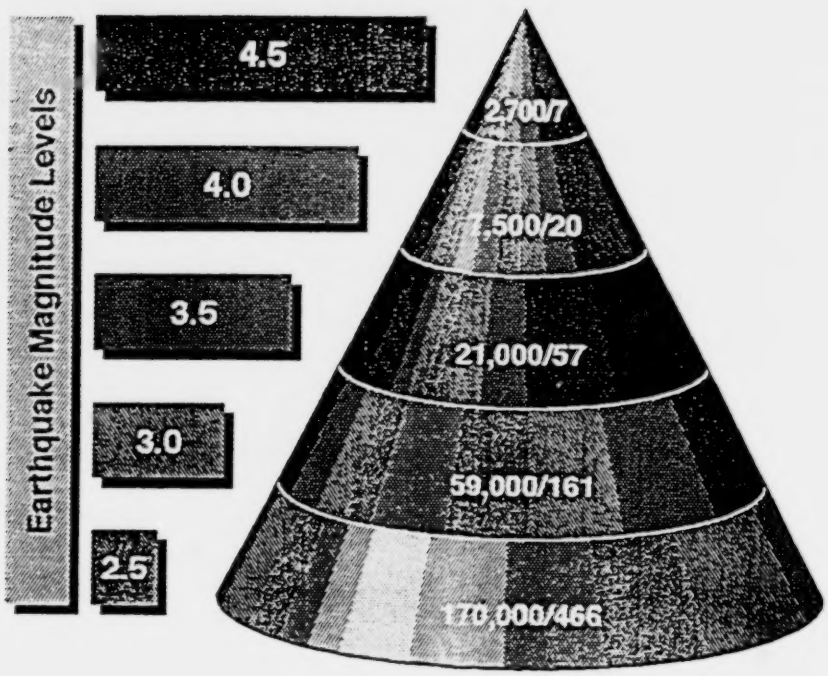

Fig.1. Average number of earthquakes per year/day at a given magnitude or greater

Fig. 2. Preliminary GSETT-3 Alpha network. The filled symbols represent existing or planned stations. The open symbols denote additional stations that are proposed to be located in certain general geographical regions so as to improve the global coverage. The additional stations could be chosen either from existing stations or by installation of new facilities.

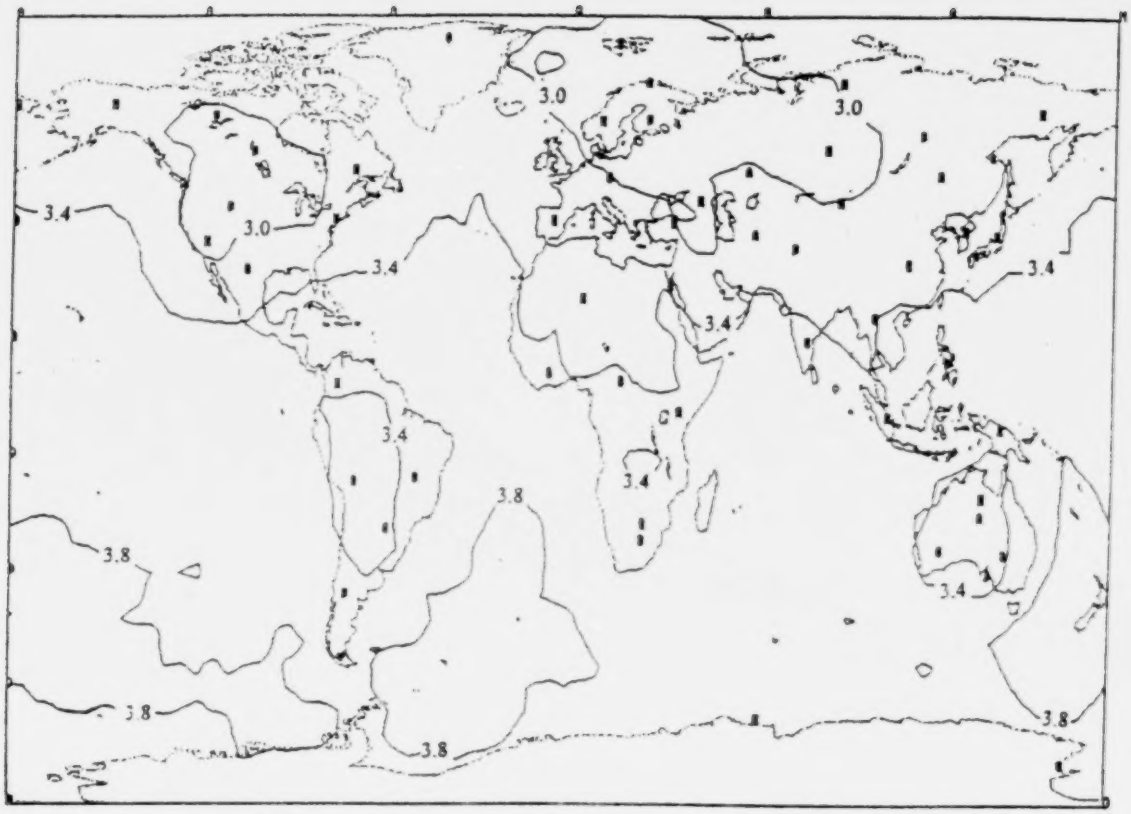

Fig. 3. Estimated event detection capability for the proposed GSETT-3 network in terms of seismic magnitude. The contours indicate 3.0, 3.4 and 3.8 detection thresholds (90% probability for detection at 3 or more stations). In parts of Europe and North America the detection threshold is below 3.0 and in some continental areas of the southern hemisphere it is above 3.4.

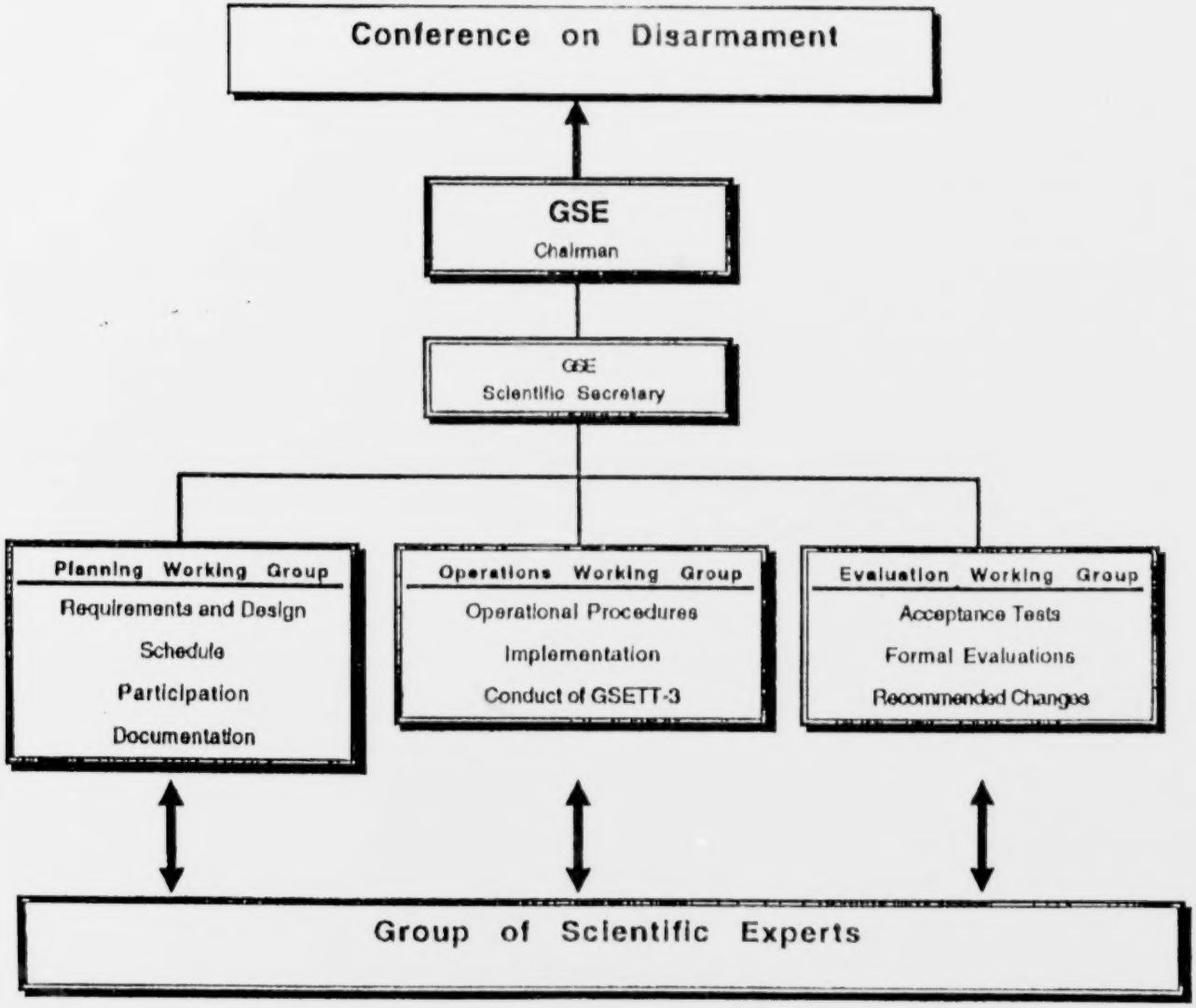

Fig. 4. Organization for the oversight of GSETT-3.

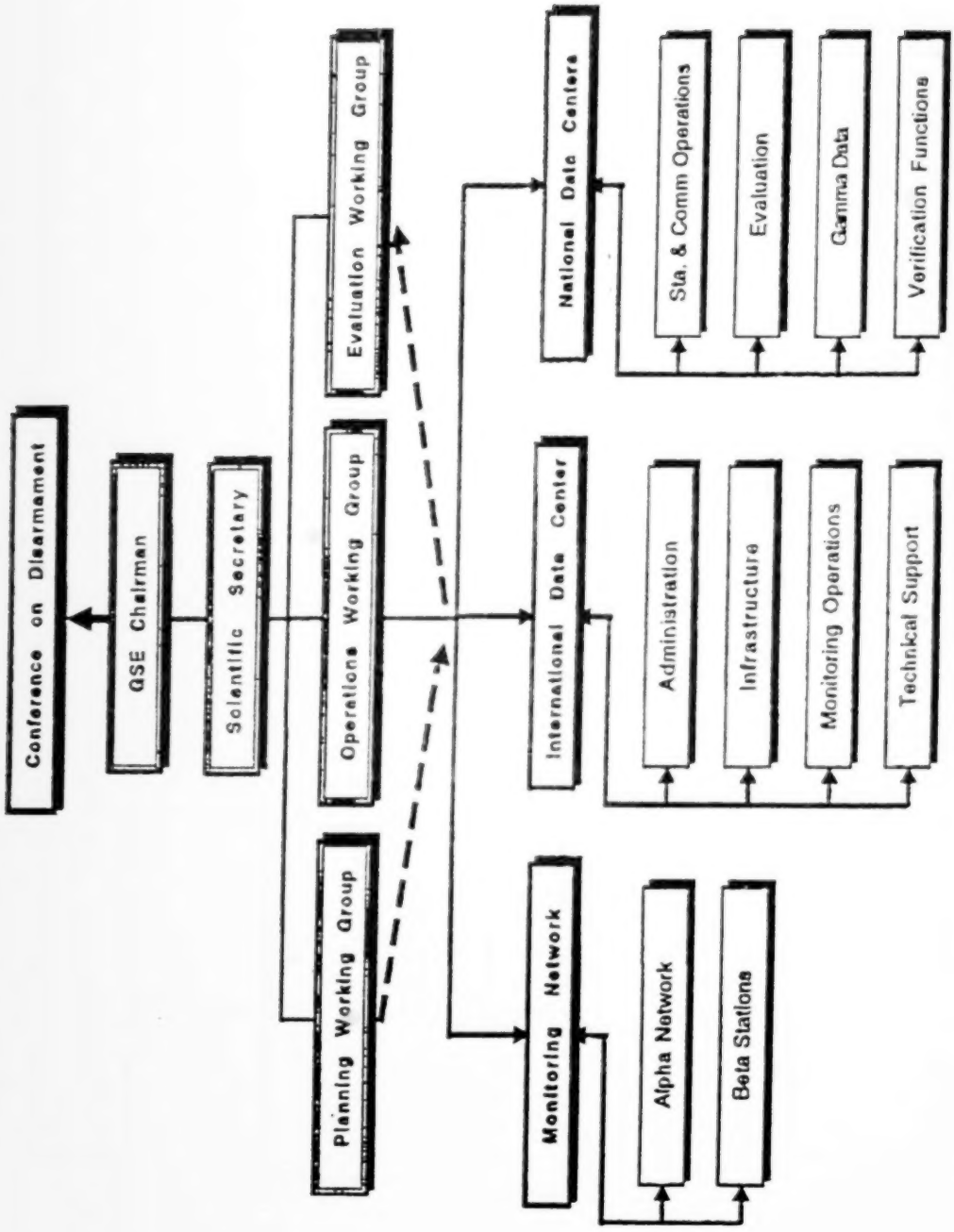

Fig. 5. Organization for the conduct of GSETT-3.